(51) International Patent Classification 6 :		(11) International Publication Number:	WO 98/16014
Ĥ03M 7/30	A1	(43) International Publication Date:	16 April 1998 (16.04.98)

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(54) Title: DATA COMPRESSION AND EXPANSION OF AN AUDIO SIGNAL

(57) Abstract

A data compression apparatus is disclosed for data compressing an audio signal. The data compression apparatus comprises an input terminal (1) for receiving the audio signal, a 1–bit A/D converter (4) for A/D converting the audio signal so as to obtain a bitstream signal, a lossless coder (10) for carrying out a lossless data compression step on the bitstream signal so as to obtain a data compressed bitstream signal, and an output terminal (14) for supplying the data compressed bitstream signal. Further, a recording apparatus and a transmitter apparatus comprising the data compression apparatus are disclosed. In addition, a data expansion apparatus for data expanding the data compressed bitstream signal supplied by the data compression apparatus is disclosed, as well as a reproducing apparatus and a receiver apparatus comprising the data expansion apparatus.

Data compression and expansion of an audio signal.

The invention relates to a data compression apparatus for data compress-
ing an audio signal, to a data compression method, a transmitter comprising the data
compression apparatus, a recording apparatus comprising the data compression apparatus, a
record carrier having the data compressed audio signal recorded on it in a track of said
5   record carrier, to a data expansion apparatus for data expanding a data compressed audio
signal, to a data expansion method, a receiver comprising the data expansion apparatus and
to a reproducing apparatus comprising the data expansion apparatus.

10   Data compression on an audio signal is well known in the art. Reference
is made in this respect to EP-A 402,973, document D1 in the list of related documents. The
document describes a subband coder, in which an audio signal is A/D converted with a
specific sampling frequency, such as 44.1 kHz, and the resulting samples in de form of eg.
24 bits wide words of the audio signal, are supplied to a subband splitter filter. The subband
15   splitter filter splits the wideband digital audio signal into a plurality of relatively narrow band
subband signals. Using a psycho acoustic model, a masked threshold is derived and blocks of
samples of the subband signals are subsequently quantised with a specific number of bits per
sample for each block of the subband signals, in response to said masked threshold, resulting
in a significant data compression of the audio signal to be transmitted. The data compression
20   carried out is based on 'throwing away' those components in the audio signal that are
inaudible and is thus a lossy compression method. The data compression described in
document D1 is a rather intelligent data compression method and requires a substantial
number of gates or instructions, when realized in hard or software respectively, so that it is
expensive. Moreover, the subsequent expansion apparatus also requires a substantial number
25   of gates or instructions, when realized in hardware or software respectively.

The invention aims at providing a data compression apparatus for data
compressing an audio signal such that it is more simple and that the corresponding expander

apparatus can also be more simple and less expensive.

The data compression apparatus in accordance with the invention comprises

- input means for receiving the audio signal,

5 - conversion means for carrying out a conversion on the audio signal so as to obtain a 1-bit bitstream signal, the conversion means comprising sigma-delta modulator means,

- lossless coding means for carrying out a substantially lossless data compression step on the bitstream signal so as to obtain a data compressed bitstream signal,

10 and

- output means for supplying the data compressed bitstream signal. More specifically, when the audio signal is an analog audio signal, the conversion means is in the form of A/D conversion means for carrying out a 1-bit A/D conversion on the analog audio signal so as to obtain said bitstream signal.

15 The invention is based on the following recognition. The audio signal can be applied in analog form or in digital form. When A/D converting, in accordance with the invention, an analog audio signal with a 1-bit A/D converter (also named: bitstream converter or sigma-delta modulator), the audio signal to be A/D converted is sampled with a frequency which is generally a multiplicity of the frequency of 44.1 kHz or 48 kHz. The

20 output signal of the 1-bit A/D converter is a binary signal, named bitstream signal. When the audio signal is supplied in digital form, sampled at eg. 44.1 kHz, the samples being expressed in eg. 16 bits per sample, this digital audio signal is oversampled with a frequency which is again a multiplicity of this sampling frequency of 44.1 kHz (or 48 kHz), which results in the 1-bit bitstream signal.

25 Converting an audio signal into a 1-bit bitstream signal has a number of advantages. Bitstream conversion is a high quality encoding method, with the possibility of a high quality decoding or a low quality decoding with the further advantage of a simpler decoding circuit. Reference is made in this respect to the publications 'A digital decimating filter for analog-to-digital conversion of hi-fi audio signals', by J.J. van der Kam, document

30 D2 in the list of related documents, and 'A higher order topology for interpolative modulators for oversampling A/D converters', by Kirk C.H. Chao et al, document D3 in the list of related documents.

1-bit D/A converters are used in CD players, as an example, to reconvert the bitstream audio signal into an analog audio signal. The audio signal recorded on a CD

~disk is however not a data compressed 1-bit bitstream signal.

It is well known in the art that the resulting bitstream signal of the 1-bit A/D converter is, roughly said, a random signal which has a 'noisy-like' frequency spectrum. Such types of signals are hard to data compress.

Surprisingly, however, it was established that using a lossless coder, such as a variable length coder in the form of a Huffman coder or an arithmetic coder, a significant data reduction could be obtained, in spite of the noisy character of the bitstream signal from the 1-bit A/D converter.

These and other aspects of the invention will be apparent from and elucidated further with reference to the embodiments described in the following figure description, in which

figure 1 shows an embodiment of the data compression apparatus,

figure 2a shows the frequency spectrum of the output signal of the 1-bit A/D converter and figure 2b shows the frequency spectrum of the same output signal in a smaller frequency range,

figure 3 shows the data compression apparatus incorporated in a recording apparatus for recording the data compressed bitstream signal on a record carrier,

figure 4 shows the data compression apparatus incorporated in a transmission apparatus for transmitting the data compressed bitstream signal via a transmission medium,

figure 5 shows an embodiment of the data expansion apparatus,

figure 6 shows the data expansion apparatus incorporated in a reproducing apparatus for reproducing the data compressed bitstream signal from a record carrier, and

figure 7 shows the data expansion apparatus incorporated in a receiving apparatus for receiving the data compressed bitstream signal from a transmission medium.

figure 8 shows a further embodiment of the recording apparatus further provided with an error correction encoder and a channel encoder,

figure 9 shows a further embodiment of the reproducing apparatus further provided with a channel decoder and an error correction unit,

figure 10 shows an embodiment of the data compression apparatus in which the lossless coder is in the form of an arithmetic coder, and

figure 11 shows an embodiment of the data expansion apparatus in which

the lossless decoder is in the form of an arithmetic decoder.

Figure 1 shows an embodiment of the data compression apparatus,

5   comprising an input terminal 1 for receiving the audio signal. In the present example, the
audio signal is an analog audio signal. The input terminal 1 is coupled to an input 2 of a 1-
bit A/D converter 4, also called: sigma-delta modulator. An output 6 of the 1-bit A/D
converter 4 is coupled to an input 8 of a data compression unit 10. An output 12 of the data
compression unit 10 is coupled to an output terminal 14.

10   The 1-bit A/D converter 4 is adapted to carry out a 1-bit A/D conversion
on the audio signal so as to obtain a bitstream signal which is supplied to the output 6. To
that purpose, the A/D converter 4 receives a sampling frequency equal to $N.f_s$ via an input
16. f_s is a frequency equal to eg. 32 kHz, 44.1 kHz or 48 kHz and N is a large number,
such as 64. The audio signal is sampled in the A/D converter 4 with a sampling frequency of

15   eg. 2.8224 MHz (64 x 44.1 kHz). The bitstream signal appearing at the output 6 of the A/D
converter thus has a bitrate of 2.8224 MHz.

The data compression unit 10 is in the form of a lossless coder. Lossless
coders have the advantage that they can data compress the audio signal in such a way that,
after data expansion by a lossless decoder, the original audio signal can be reconstructed in a

20   substantially lossless way. That means that there is substantially no loss of information after
compression-expansion. Lossless coders can be in the form of a variable length coder.
Variable length coders are well known in the art. Examples of such variable length coders
are Huffman coders, arithmetic coders and Lempel-Ziv coders. Reference is made in this
respect to the publications 'A method for the construction of minimum-redundancy codes' by

25   D.A. Huffman, document D4 in the list of related documents, 'An introduction to arithmetic
coding' by G.G. Langdon, document D5 in the list of related documents, and 'A universal
algorithm for sequential data compression' by J. Ziv et al, document D6 in the list of related
documents.

The data compression unit 10 carries out a substantially lossless data

30   compression step on the bitstream signal so as to obtain a data compressed bitstream signal at
its output 12, which is supplied to the output terminal 14.

Figure 2a shows a frequency spectrum of the bitstream signal present at
the output 6 of the A/D converter 4, for an input signal in the form of a 5 kHz sinusoid,
sampled with a sampling frequency of 2.8224 MHz. The spectrum thus shows frequencies

between 0 Hz and 1.4 MHz. Figure 2b shows part of the spectrum shown in figure 2a, namely that part between 0 Hz and 100 kHz, so as to more clearly show the 5 kHz sinusoid comprised in the bitstream signal. Clearly visible is the noise-like character of the bitstream signal, especially in the higher frequency region, which seems to imply that carrying out data
5   compression on the said signal will not result in a substantial amount of data reduction.

Contrary to this, investigations have made clear that a significant data reduction can be obtained. In the following table, the results of the data compression realized by three lossless coders are given for three different music fragments:

fragment	δ		
	Huffman (8 b)	Hufmann (16 b)	Lempel-Ziv
bossanova	1.31	1.45	1.73
jazz	1.35	1.50	1.77
classical music	1.38	1.59	1.86

where δ is the compression ratio, defined as the ratio of the bitrate of the input signal of the coder to the bitrate of the output signal of the coder.

Figure 3 shows an embodiment of a recording apparatus comprising the data compression apparatus shown in figure 1. The recording apparatus further comprises a
20   write unit 30 for writing the data compressed bitstream signal in a track on the record carrier 32. In the present example, the record carrier 32 is a magnetic record carrier, so that the write unit 30 comprises at least one magnetic head 34 for writing the data compressed bitstream signal in the record carrier 32. The record carrier may however be an optical record carrier, such as a CD disk or a DVD disk.

25   Figure 4 shows an embodiment of a transmitter for transmitting an audio signal via a transmission medium TRM, comprising the data compression apparatus as shown in figure 1. The transmitter further comprises a transmission unit 40 for applying the data compressed bitstream signal to the transmission medium TRM. The transmission unit 40 could comprise an antenna 42.

30   Transmission via a transmission medium, such as a radio frequency link or a record carrier, generally requires an error correction encoding and a channel encoding carried out on the data compressed bitstream signal to be transmitted. Figure 8 shows such

signal processing steps carried out on the data compressed bitstream signal for the recording arrangement of figure 3. The recording arrangement of figure 8 therefore comprises an error correction encoder 80, well known in the art, and a channel encoder 82, also well known in the art.

5   Figure 5 shows an embodiment of the data expansion apparatus. The apparatus has an input terminal 50 for receiving the data compressed audio signal which is in the form of the data compressed bitstream signal, as supplied by the data compression apparatus of figure 1. The input terminal 50 is coupled to an input 52 of a data expansion unit 54, which has an output 56 which is coupled to an input 58 of a 1-bit D/A converter 60.

10   An output 62 of the converter 60 is coupled to an output terminal 64.

The data expansion unit 54 is a lossless decoder, such as a variable length decoder in the form of eg. a Huffman decoder or an arithmetic decoder. It will be clear that the decoder in the data expansion apparatus of figure 5 should be the inverse of the encoder used in the data compression apparatus of figure 1, in order to realize a substantially lossless

15   encoding-decoding step. The data expansion unit 54 expands the data compressed bitstream so as to obtain a replica of the original bitstream, which is supplied to the input 58 of the D/A converter 60. The converter 60 converts the bitstream into an analog audio signal which is supplied to the terminal 64.

Figure 6 shows the data expansion apparatus of figure 5 incorporated in a

20   reproduction apparatus. The reproducing apparatus further comprises a read unit 70 for reading the data compressed bitstream signal from a track on the record carrier 32. In the present example, the record carrier 32 is a magnetic record carrier, so that the read unit 70 comprises at least one magnetic head 72 for reading the data compressed bitstream signal from the record carrier 32. The record carrier may however be an optical record carrier,

25   such as a CD disk or a DVD disk.

Figure 7 shows an embodiment of a receiver for receiving an audio signal via a transmission medium TRM, comprising the data expansion apparatus as shown in figure 5. The receiver further comprises a receiving unit 75 for receiving the data compressed bitstream signal from the transmission medium TRM. The receiving unit 75 could comprise

30   an antenna 77.

As has been explained above, transmission via a transmission medium, such as a radio frequency link or a record carrier, generally requires an error correction encoding and a channel encoding carried out on the data compressed bitstream signal to be transmitted, so that a corresponding channel decoding and error correction can be carried out

upon reception. Figure 9 shows the signal processing steps of channel decoding and error
correction carried out on the received signal, received by the reading means 70 for the
reproducing arrangement of figure 6. The reproducing arrangement of figure 9 therefore
comprise a channel decoder 90, well known in the art, and an error correction unit 92, also
5   well known in the art, so as to obtain a replica of the data compressed bitstream signal.

Another data compression apparatus is shown in figure 10. In the data
compression apparatus of figure 10, the bitstream signal is supplied to an input 8 of a
lossless coder, which is in the form of an entropy coder, such as an arithmetic coder 154.
Further the bitstream signal is also an input of a prediction filter unit 152. An output of the
10 prediction filter unit 152 is coupled to an input of a probability determining unit 156. The
arithmetic coder 154 encodes the bitstream signal into a data compressed bitstream signal in
response to probability values p supplied to its input 192. The probability determining unit
156 determines a probability value indicating the probability that a bit in the bitstream signal
supplied by the converter unit 4 has a predetermined logical value, such as '1'. This
15 probability value, denoted p in figure 10, is supplied to the arithmetic coder 154 so as to
enable the data compression of the bitstream signal in the arithmetic coder 154. The
determining unit 156 determines this probability value from the output signal of the predic-
tion filter 152. The arithmetic coder 154 can data compress the bitstream signal on a frame-
by-frame basis.

20   The functioning of the apparatus of figure 10 is as follows. The prediction filter
152 realizes a prediction filtering on the bitstream signal so as to obtain a multi bit output
signal. The multi bit output signal has a plurality of levels within a range of eg. +3 and -3.
Further, for each of a plurality of subintervals in the value range of the multi bit output
signal, it is determined what the probability is that the corresponding bit in the bitstream
25 signal is eg. a '1' bit. This can be realized by counting the number of 'ones' and 'zeroes'
occurring in the bitstream signal during a specific time interval, when the multi bit output
signal falls in one of such ranges. The probabilities thus obtained for the various values in
the multi bit output signal are subsequently supplied as the probability signal p to the
arithmetic coder 154. The data compressed bitstream signal is supplied by the arithmetic
30 coder 154 to an output line 158, for transmission via a transmission medium TRM or a
record carrier.

Figure 11 shows a corresponding data expansion apparatus for decoding the
data compressed bitstream signal, received via the transmission medium TRM. The data
processing apparatus of figure 11 comprises an entropy decoder 172, which receives the data

compressed bitstream signal via an input 174. In the present example, the entropy decoder 172 is in the form of an arithmetic decoder that carries out an arithmetic decoding step on the data compressed bitstream signal under the influence of a probability signal p, supplied to an input 176 so as to generate a replica of the original bitstream signal which is supplied to 5 an output 178. The replica is supplied to an input 58 of the reconverter unit 60.

Further, a probability supply unit 180 is present for supplying the probability signal p to the arithmetic decoder 172. The probability signal p can be obtained in different ways, dependent on how the probability signal has been derived in the encoder. One way is, to derive the probability signal p in an adaptive way from the output signal of a prediction 10 filter 181. In this embodiment, the prediction filter 181 is equivalent to the prediction filter 152 in the encoder and the probability supply unit180 is equivalent to the probability determining unit 156 in the encoder of figure 10. Another way of generating the probability signal p, is by using side information received via the transmission medium TRM, as will be explained hereafter.

15 Side information can be generated by the apparatus of figure 10 for transmission to the apparatus of figure 11. Such side information can include the filter coefficients for the filter 152 that are determined on a frame by frame basis, which coefficients are transmitted to the corresponding prediction filter included in the unit 180.

Further, the apparatus of figure 10 can generate parameters that describe the 20 conversion of the multi bit output signal of the prediction filter 152 into the probability signal p. Such parameters are also included in the side information and transmitted to the supply unit 180 and the filter 181, so as to enable the regeneration of the probability signal p in the apparatus of figure 11 on the basis of the multi bit output signal provided by the prediction filter 181.

25 The entropy encoder used in the embodiment of figure 10 is adapted to encode the bitstream signal using a probability signal in order to obtain the data compressed bitstream signal. One such entropy encoder is the arithmetic coder described above. One other type of such entropy coder is, as an example, the well known finite state coder. The entropy decoder used in the embodiment of figure 11 is adapted to decode the data com- 30 pressed bitstream signal using a probability signal in order to obtain a replica of the bitstream signal. One such entropy decoder is the arithmetic decoder described above. One other type of such entropy decoder is, as an example, the well known finite state decoder.

Whilst the invention has been described with reference to preferred embodiments thereof, it is to be understood that these are not limitative examples. Thus, various

modifications may become apparent to those skilled in the art, without departing from the scope of the invention, as defined by the claims. When the audio signal is supplied in digital form, such as sampled at 44.1 kHz and the samples being expressed in eg. 16 bits, the conversion means are adapted to oversample the digital audio signal with eg. the frequency

5   of 64 x 44.1 kHz so as to obtain the 1-bit bitstream signal.

It should further be noted that the invention also applies to an embodiment in which the bitstream signal, as supplied by the converter 4 has undergone an additional signal processing step resulting in a processed 1-bit bitstream signal that is supplied to the lossless coder 10. Such additional signal processing step could include merging a left and right hand

10   signal component of a stereo audio signal, in 1-bit bitstream form, into a processed 1-bit bitstream signal.

Further, the invention lies in each and every novel feature or combination of features.

- List of related documents

(D1)   EP-A 402,973 (PHN 13.241)

(D2)   'A digital decimating filter for analog-to-digital conversion of hi-fi audio

5   signals', by J.J. van der Kam in Philips Techn. Rev. 42, no. 6/7, April 1986,

         pp. 230-8

(D3)   'A higher order topology for interpolative modulators for oversampling A/D

         converters', by Kirk C.H. Chao et al in IEEE Trans. on Circuits and Systems,

         Vol 37, no. 3, March 1990, pp. 309-18

10 (D4) 'A method for the construction of minimum-redundancy codes', by D.A.

         Huffman in Proc. of the IRE, Vol. 40(10), September 1952.

(D5)   'An introduction to arithmetic coding' by G.G. Langdon, IBM J. Res. Devel-

         op., Vol. 28(2), March 1984.

(D6)   'A universal algorithm for sequential data compression' by J. Ziv et al, IEEE

15   TRans. on Inform. Theory, Vol. IT-23, 1977.

- CLAIMS

1.   Data compression apparatus for data compressing an audio signal, the data
compression apparatus comprising

-           input means for receiving the audio signal,

-           conversion means for carrying out a conversion on the audio signal so as to
5   obtain a 1-bit bitstream signal, the conversion means comprising sigma-delta
            modulator means,

-           lossless coding means for carrying out a substantially lossless data compression
            step on the bitstream signal so as to obtain a data compressed bitstream signal,
            and

10 -   output means for supplying the data compressed bitstream signal.

2.   Data compression apparatus as claimed in claim 1, wherein the audio
signal is an analog audio signal and the conversion means being in the form of A/D
conversion means for carrying out a 1-bit A/D conversion on the analog audio signal so as to
obtain said bitstream signal.

15 3.   Data compression apparatus as claimed in claim 1 or 2, wherein the
lossless coding means comprise a variable length coder.

4.   Data compression apparatus as claimed in claim 3, wherein the variable
length coder is a Huffman coder.

5.   Data compression apparatus as claimed in claim 3, wherein the variable
20 length coder is an arithmetic coder.

6.   Data compression method for data compressing an audio signal, the data
compression method comprising the steps of

-           receiving the audio signal,

-           carrying out a conversion on the audio signal so as to obtain a 1-bit bitstream
25   signal, the conversion step comprising a sigma-delta modulation step,

-           carrying out a substantially lossless data compression step on the bitstream
            signal so as to obtain a data compressed bitstream signal, and

-           supplying the data compressed bitstream signal.

7.   Transmitter for transmitting an audio signal via a transmission medium,

- comprising the data compression apparatus as claimed in anyone of the claims 1 to 5, wherein the transmitter further comprises

     - transmission means for applying the data compressed bitstream signal to the transmission medium.

5   8.   Recording apparatus for recording an audio signal on a record carrier, comprising the data compression apparatus as claimed in anyone of the claims 1 to 5, wherein the recording apparatus further comprises

     - writing means for writing the data compressed bitstream signal in a track on the record carrier.

10 9.   Recording apparatus as claimed in claim 8, wherein the record carrier is an optical or a magnetic record carrier.

10.   Record carrier having a data compressed bitstream signal recorded on it in a track of said record carrier.

11.   Data expansion apparatus for data expanding a data compressed audio

15 signal so as to obtain a replica of an original audio signal, the data expansion apparatus comprising

     - input means for receiving the data compressed audio signal which is in the form of a data compressed bitstream signal,

     - lossless decoding means for carrying out a substantially lossless data expansion

20   step on the data compressed bitstream signal so as to obtain a bitstream signal,

     - D/A conversion means for carrying out a D/A conversion on the bitstream signal so as to obtain the replica of the original audio signal,

     - output means for supplying the replica of the original audio signal.

12.   Data expansion apparatus as claimed in claim 11, wherein the D/A

25 conversion means comprise a sigma-delta demodulator.

13.   Data expansion apparatus as claimed in claim 11 or 12, wherein the lossless decoding means comprise a variable length decoder.

14.   Data expansion apparatus as claimed in claim 13, wherein the variable length decoder is a Huffman decoder.

30 15.   Data expansion apparatus as claimed in claim 13, wherein the variable length decoder is an arithmetic decoder.

16.   Data expansion method for data expanding a data compressed audio signal so as to obtain a replica of an original audio signal, the data expansion method comprising the steps of

receiving the data compressed audio signal which is in the form of a data compressed bitstream signal,

- carrying out a substantially lossless data expansion step on the data compressed bitstream signal so as to obtain a bitstream signal,

5 - carrying out a D/A conversion on the bitstream signal so as to obtain the replica of the original audio signal,

- supplying the replica of the original audio signal.

17. Receiver for receiving an audio signal via a transmission medium, comprising the data expansion apparatus as claimed in anyone of the claims 11 to 15, 10 wherein the receiver further comprises

- receiving means for retrieving the data compressed bitstream signal from the transmission medium.

18. Reproducing apparatus for reproducing an audio signal from a record carrier, comprising the data expansion apparatus as claimed in anyone of the claims 11 to 15, 15 wherein the reproducing apparatus further comprises

- reading means for reading the data compressed bitstream signal from a track on the record carrier.

19. Transmitter as claimed in claim 7, wherein the transmitter further comprises error correction encoding means and/or channel encoding means, for error 20 correction encoding and/or channel encoding the data compressed bitstream signal prior to applying the data compressed bitstream signal to the transmission medium.

20. Transmitter as claimed in claim 8, further comprising error correction encoding means and/or channel encoding means, for error correction encoding and/or channel encoding the data compressed bitstream signal prior to writing the data compressed 25 bitstream signal on the record carrier.

21. Receiver as claimed in claim 17, wherein the receiver further comprises channel decoding means and/or error correction means, for channel decoding and/or error correcting the signal retrieved from the transmission medium so as to obtain said data compressed bitstream signal

30 22. Reproducing apparatus as claimed in claim 18, further comprising channel decoding means and/or error correction means, for channel decoding and/or correcting the signal read from the record carrier so as to obtain said data compressed bitstream signal.

23. Data compression apparatus for data compressing an audio signal, the data compression apparatus comprising

input means for receiving the audio signal,

- conversion means for carrying out a conversion on the audio signal so as to obtain a 1-bit bitstream signal, the conversion means comprising sigma-delta modulator means,

5 - lossless coding means for carrying out a substantially lossless data compression step on the bitstream signal so as to obtain a data compressed bitstream signal, and

- output means for supplying the data compressed bitstream signal,

said lossless compression means comprising

10 - an entropy encoder for entropy encoding the bitstream signal in response to a probability signal so as to obtain said data compressed bitstream signal,

- prediction means for carrying out a prediction step on the bitstream signal, and

- probability signal determining means for determining said probability signal from said prediction means.

15 24.   Data compression apparatus as claimed in claim 23, wherein the prediction means comprise prediction filter means for carrying out a prediction filter operation on the bitstream signal so as to obtain a multi value output signal, and wherein said probability determining means are adapted to derive said probability signal from said multi value output signal.

20 25.   Data compression method for data compressing an audio signal, the data compression method comprising the steps of

- receiving the audio signal,

- carrying out a conversion on the audio signal so as to obtain a 1-bit bitstream signal, the conversion step comprising a sigma-delta modulation step,

25 - carrying out a substantially lossless data compression step on the bitstream signal so as to obtain a data compressed bitstream signal, and

- supplying the data compressed bitstream signal,

said lossless compression step comprising the substeps of

- entropy encoding the bitstream signal in response to a probability signal so as to 30 obtain said data compressed bitstream signal,

- carrying out a prediction step on the bitstream signal, and

- determining said probability signal from said prediction means.

26.   Data compression method as claimed in claim 25, wherein the prediction step comprises the substep of carrying out a prediction filter operation on the bitstream signal so

- as to obtain a multi value output signal, and wherein said probability determining step comprises the substep of deriving said probability signal from said multi value output signal.

27.   Data expansion apparatus for data expanding a data compressed audio signal so as to obtain a replica of an original audio signal, the data expansion apparatus comprising

-       input means for receiving the data compressed audio signal which is in the form of a data compressed bitstream signal,

-       lossless decoding means for carrying out a substantially lossless data expansion step on the data compressed bitstream signal so as to obtain a bitstream signal,

-       D/A conversion means for carrying out a D/A conversion on the bitstream signal so as to obtain the replica of the original audio signal,

-       output means for supplying the replica of the original audio signal,

wherein said lossless decoding means comprise

- an entropy decoder for entropy decoding the data compressed bitstream signal in response to a probability signal so as to obtain said bitstream signal, and

- probability signal generator means for supplying said probability signal.

28.   Data expansion apparatus as claimed in claim 27, wherein said entropy decoder is an arithmetic decoder.

29.   Data expansion method for data expanding a data compressed audio signal so as to obtain a replica of an original audio signal, the data expansion method comprising the steps of

-       receiving the data compressed audio signal which is in the form of a data compressed bitstream signal,

-       carrying out a substantially lossless data expansion step on the data compressed bitstream signal so as to obtain a bitstream signal,

-       carrying out a D/A conversion on the bitstream signal so as to obtain the replica of the original audio signal,

-       supplying the replica of the original audio signal,

wherein said lossless decoding step comprises the substeps of

-       entropy decoding the data compressed bitstream signal in response to a probability signal so as to obtain said bitstream signal, and

-       supplying said probability signal.

30.   Data expansion method as claimed in claim 29, wherein said entropy decoding step comprises an arithmetic decoding step.
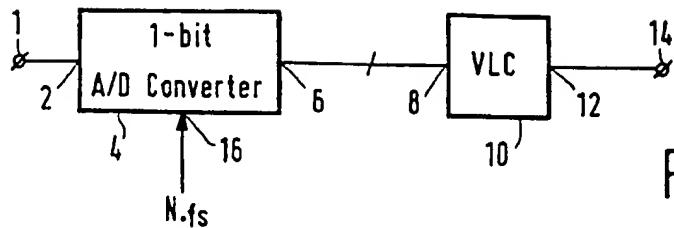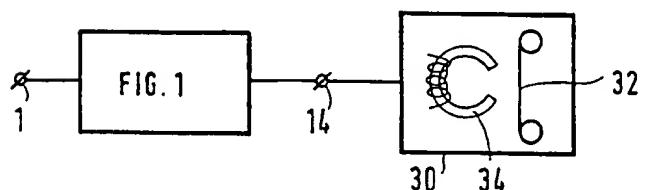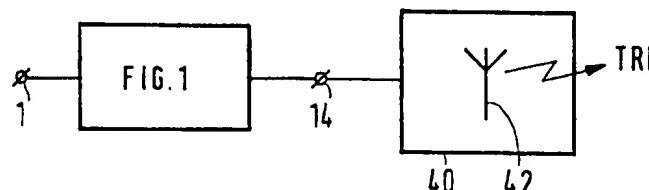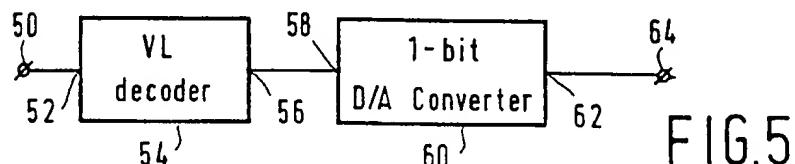
FIG.1


FIG.3


FIG.4

FIG.5
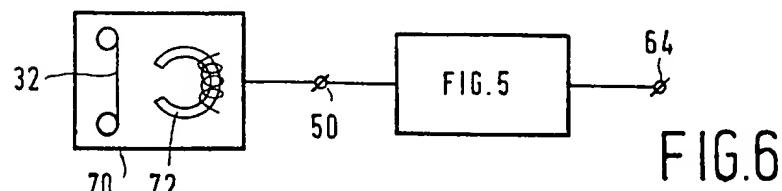
FIG.6
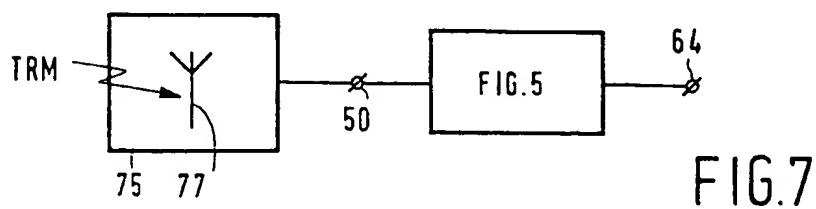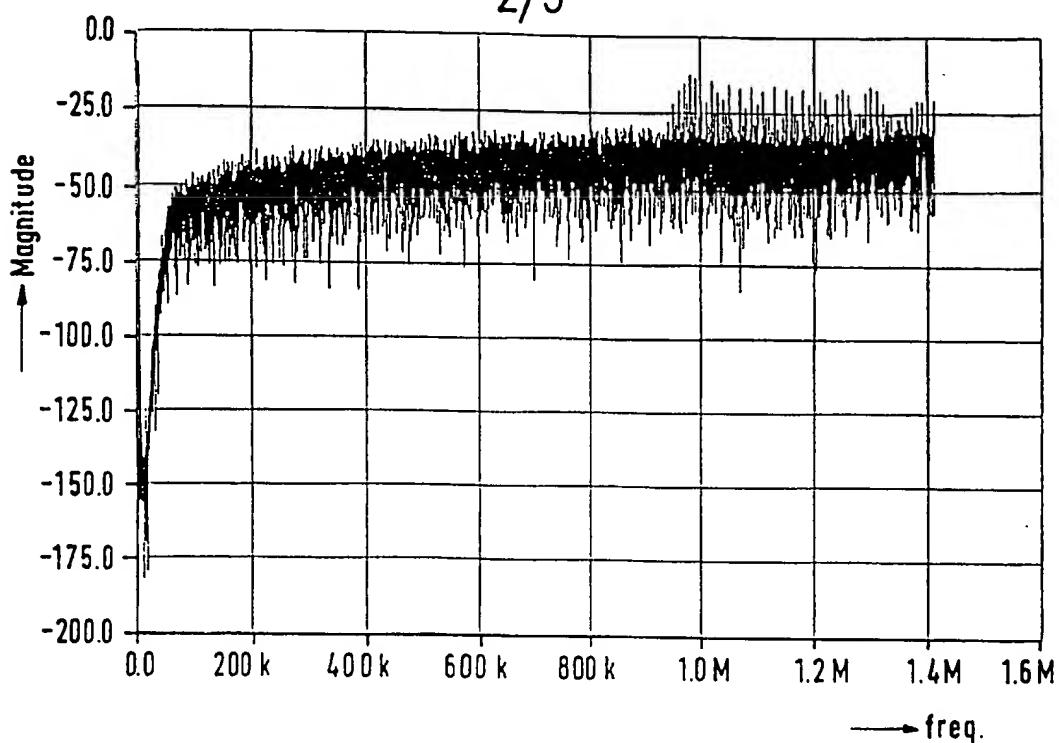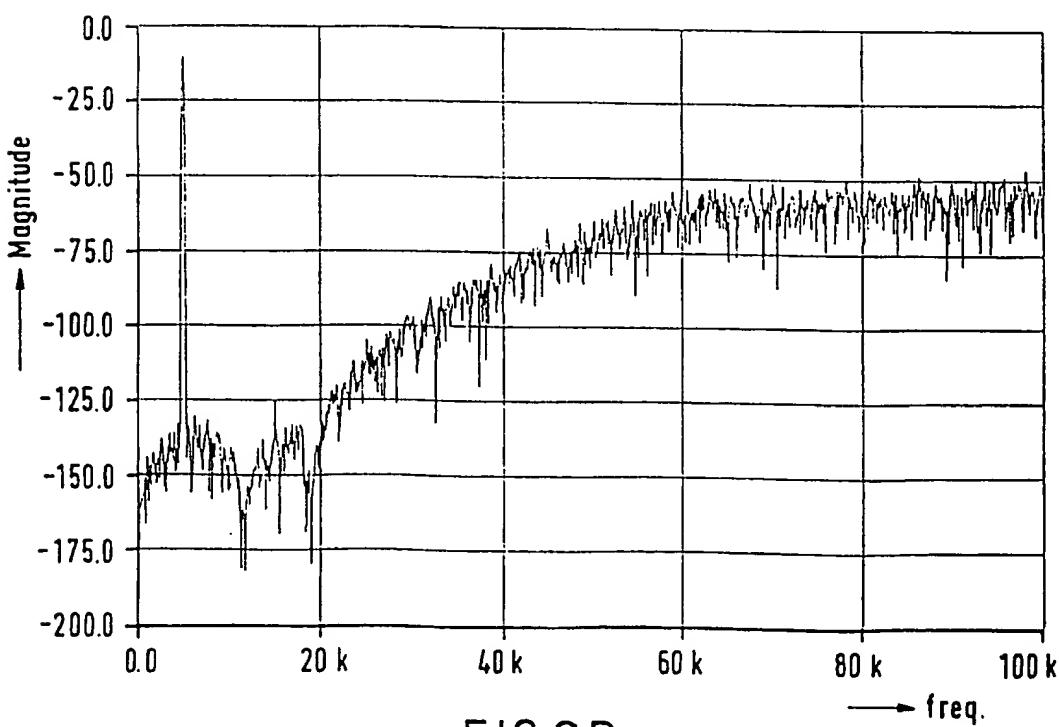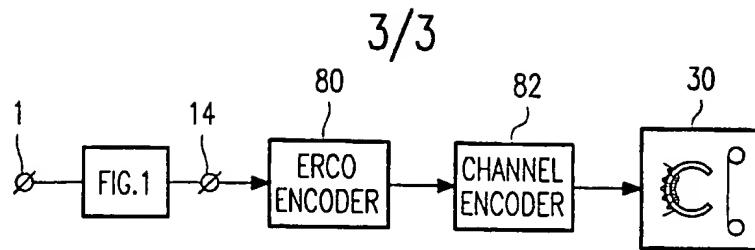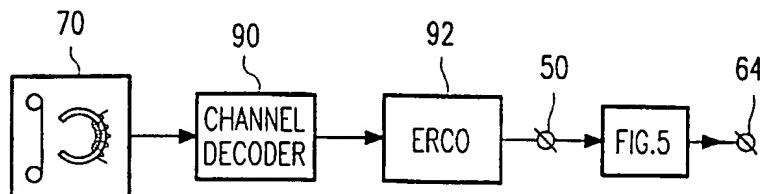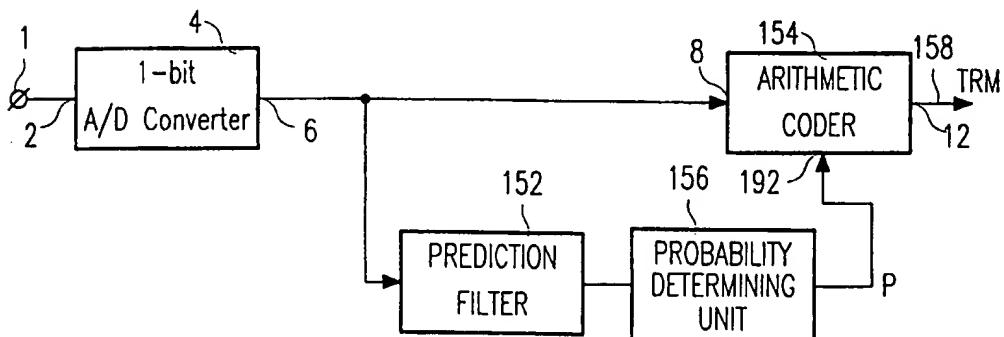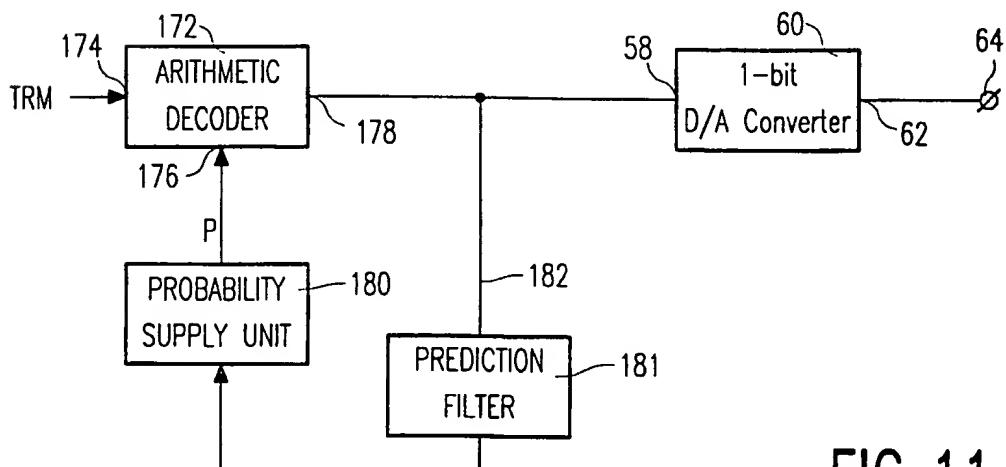
FIG.7

FIG.2A

FIG.2B

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FIG. 8

FIG. 9

FIG. 10

FIG. 11

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H03M 7/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	Patent Abstracts of Japan, Vol 17,No 301, E-1378 abstract of JP 5-22288 A (FUJITSU GENERAL LTD), 29 January 1993 (29.01.93)	1-30
A	US 5561688 A (RONALD H. JONES, JR), 1 October 1996 (01.10.96), abstract	1-30
A	JP 7297646 A (SONY CORP), 10 November 1995 (10.11.95), abstract	1-30

| X | Further documents are listed in the continuation of Box C. | X | See patent family annex. |

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Date of the actual completion of the international search	Date of mailing of the international search report
18 March 1998	19 -03- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Rune Bengtsson Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 97/01156

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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